V. Research strategies for ITCT

A. Research tools

3-dimensional models are required to quantitatively answering the ITCT research questions outlined in section 3. They must resolve the coupling between transport, chemistry, and aerosol processes on synoptic scales and finer. Such models already exist but their quality is highly uncertain. They need to be constrained and tested with atmospheric observations to a much more deliberate degree than has been achieved so far. One aspect of the experimental design for ITCT therefore involves a close coupling of atmospheric observations and models, in which the models are driven by assimilated meteorological observations for the period of interest, and the observations are targeted towards testing the key relevant features of the models. As discussed below, observations from ground-based, aircraft, and satellite platforms all have important roles to play in this design, both in testing model features, and in providing a wider base of exploratory measurements. Ship platforms are not specifically discussed but share some of the advantages and disadvantages of ground-based and aircraft platforms.

Ground-based platforms have two primary strengths. First, they provide the opportunity for field programs that simultaneously measure a broad spectrum of gaseous and aerosol species by research grade, prototype instrumentation. Such field studies expand the observational database that allows the identification and investigation of crucial atmospheric processes. During these studies many species can be measured by two or more techniques to allow for intercomparison of results. Such intercomparison efforts are critical for the development and improvement of measurement techniques. Second, ground-based platforms allow long-term observations at relatively low cost. Measurements can be made for a large number of species under well-calibrated conditions. A disadvantage of ground-based measurements is the lack of spatial information, which is critical for interpreting the long-range transport and chemical evolution of air masses. Lidars and sondes give vertical information but only for a few species (ozone, aerosols, water vapor). The principal roles of ground-based measurements in the ITCT context are 1) to expand the observational data base of simulataneous measurements of a broad spectrum of atmospheric species, 2) to providehigh-quality data on seasonal and interannual temporal trends, 3) to identify correlations between species that may provide important constraints for the models, and 4) to extend in time the information gained from intensive field studies.

Aircraft measurements have the advantage of providing large spatial coverage. High-quality measurements can be made from aircraft for a number of species. By designing the flight plans in the context of chemical model forecasts, the observations can be collected in a manner that provides an optimal test of models. The disadvantages of aircraft observations are limitation in flight hours, so that the data are only snapshots in time, and the limits on instrumentation dictated by aircraft payload considerations. This time limitation can be overcome to some extent with regular observations from commercial aircraft or from chartered small aircraft, but the number of measured species is then even more limited and there is less flexibility in the observational strategy.

Satellite measurements can potentially provide global and continuous observations of tropospheric composition and are in that regard ideally suited for the ITCT problem. However, for the foreseeable future only a few species will be observable from space [Singh and Jacob, 2000], the vertical resolution will be coarse (at most a few pieces of information in the troposphere), and the precision will remain limited. All current and planned satellites are in polar orbit and have a return time of 3 days or more for any given spot on the Earth; thus the data are not truly continuous. Measurements from geostationary orbit would provide truly continous observations on the scales of relevance to ITCT but these measurements are still in a technology demonstration phase.

A. Research agenda

We envision a three-pronged research agenda for ITCT involving (1) intensive field studies aimed at investigation of specific processes, (2) long-term observations to place these processes in a seasonal and interannual context, and (3) assessments directed at policy development.

Intensive field studies harness measurements from a number of platforms, together with supporting 3-D chemical transport models, into a concerted experimental design focused on answering a limited set of well-defined questions. To address the ITCT questions, these field studies must involve one or more research aircraft. Some specific plans are given in section 6. One useful tool to optimize the value of the measurements for testing the models will be to operate the models in forecast mode over the course of the intensive field study. These forecasts will then be available to guide flight planning on a day-to-day basis. Integration of satellite

observations into the experimental design may also be helpful to place the limited aircraft observations into a broader spatial context. Developing this synergy between aircraft and satellite observations may call for inclusion of satellite validation flights in the aircraft mission plans.

Long-term observations are essential to address the ITCT questions by extending temporally the information from the intensive field studies into a seasonal and multi-year frameworks. Long-term measurement platforms may include ground-based sites, ships and commercial aircraft, and small chartered aircraft. Satellites have been deployed to produce valuable long-term observations but have some important limitations discussed in section 3. The selection of platforms should be made with careful consideration of 3-D model results in order to provide the best test of the models towards addressing the ITCT questions. Eventually, the long-term measurement program may evolve into a monitoring operation to document changes in anthropogenic emissions from continental source regions and their global implications for atmospheric chemistry.

Assessment. ITCT will undertake periodic assessment of the implication of its research findings in terms of the effects of projected changes in emissions and other forcing variables (e.g., changes in land use or climate) for intercontinental transport of pollutants. In this activity ITCT hopes for a closer interaction between the policy communities of the large industrial countries. We expect that the policy community will provide guidance concerning the assessments of highest priority. These assessment needs will direct the scientific resources of the program towards the most critical uncertainties to be addressed.